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PROTECTING MEDITERRANEAN RICE-BASED AGRO-ECOSYSTEMS

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GREEN MANURE IN RICE AGRO-ECOSYSTEMS

Why use green manure?

Agricultural soils in the Po Valley (North Italy) have shown a progressive reduction in organic matter content, primarily due to the intensification of agricultural practices and the spread of simplified cropping systems, including monoculture. In this context, green manure can provide agronomic and environmental benefits, contributing to crop diversification, nutrient recycling, and maintaining soil fertility.
Green manure consists of growing a cover crop during periods when the soil is not occupied by the main crop. This provides temporary soil cover and is subsequently terminated and incorporated into the soil, returning plant biomass and nutrients to the cropping system.

Its application can provide several benefits including:

- crop diversification in rice monocrop systems;
- nutrient recycling and nutrient supply to the succeeding rice crop;
- increased organic matter content and biological activity;
- improved soil aggregation, structure, and porosity through organic matter inputs and root system activity;
- biological nitrogen fixation when legume species are used, potentially reducing the mineral nitrogen requirements of the succeeding crop.

The quantities of nutrients accumulated and subsequently returned to the soil depend on the species used, biomass production, tissue concentration, developmental stage at termination, and soil and climate conditions.
In temperate rice-growing environments, *Vicia villosa* (hairy vetch) is one of the best suited legumes for use as a winter cover crop. Literature generally reports nitrogen accumulations in the order of 60-140 kg N/ha, although, higher values can be achieved under favorable conditions and with high biomass production.

How to apply green manure?

In rice cultivation system, cover crops are applied between late October and late March-April. The choice of plant species depends on the desired objective. The most commonly used species are grasses and cruciferous plants (which primarily limit nitrogen leaching during the winter) or legumes (which provide additional nitrogen to the system through biological nitrogen fixation). Legumes, either pure or mixed, are recommended when increasing nitrogen availability is a primary objective. Among them, Vicia villosa appears to be the most adaptable to rice paddy conditions.
Using species with fasciculate roots, such as grasses with high structuring capacity (ryegrass, triticale), or species with a taproot system with decomposing properties, such as brassicas (horseradish, mustard, and rapeseed), help improve and maintain soil structure and increase soil porosity, speeding up water drainage during dry periods.

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Successful green manure management requires careful attention to sowing and termination:

- Sowing time: sowing should be done as early as possible to favour crop establishment;
- Sowing method: techniques range from simple surface distribution, distribution with light tillage (harrowing), to seeding in rows or even pre-harvest distribution via drones. No-till seeding (which could also be done by simply broadcasting the seeds onto freshly harvested rice straw) is the most economical technique but requires careful distribution of crop residues on the surface, avoiding piles. Particularly beneficial is seed distribution during rice harvest, with the distribution systems mounted directly on the combine harvester.
- Termination time: timing should be selected according to cover crop development and biomass production. Terminating the cover crop too early, with little biomass in the field, renders the practice ineffective.
- Termination method: termination of the cover crop is traditionally achieved by chopping the surface biomass, which is then buried by plowing.



Figure 1 - Mixture of *Vicia villosa* and *Lolium multiflorum*



Figure 2 - Chopping of the cover crop at the PROMEDRICE experimental site

What did we observe in PROMEDRICE?

During the two experimental seasons, a mixture of Vicia villosa and Lolium multiflorum was used.

Soil fertility

After just two years of green manure application, the main soil fertility indicators increased. Organic matter (OM) increased from 1.33 to 1.67% (+25.6%), organic carbon (OC) from 0.77 to 0.97% (+26.0%), and total nitrogen from 0.072 to 0.092% (+27.8%). The C/N ratio remained essentially unchanged.

Biomass production and nitrogen input

In 2024, the cover crop produced 6.22 t/ha of biomass in dry weight, with a nitrogen concentration of 1.36%, corresponding to a total nitrogen input of 85 kg per hectare. In 2025, biomass production was 7.15 t/ha, with an N concentration of 1.09%, corresponding to 77.9 kg of N/ha (Table 1).

Rice yield

In 2024, the adoption of green manure resulted in a rice production of 8.76 t/ha, which was 6.2% higher than the control. However, it should be noted that the drastic drop in temperatures that occurred in early September adversely affected more vigorous crops with later kernel filling, such as those treated with green manure, potentially limiting the observed production benefit. In 2025, a production of 8.57 t/ha was achieved (+14.4% compared to the control crop) (Table 2).

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Table 1 - Biomass production, nitrogen concentration and total nitrogen supply of the cover crop for green manure in the two years of experimentation

Year	Dry biomass (t ha^{-1})	Nitrogen concentration (%)	Total nitrogen input (kg N ha^{-1})
2024	6.22	1.36	85.0
2025	7.15	1.09	77.9

Table 2 - Paddy production results obtained from green manure treatment and untreated control.

Year	Green manure yield t ha^{-1}	Untreated control yield t ha^{-1}	Relevant conditions
2024	8.76	8.25	A marked temperature drop in early September have limited grain filling in the more vigorous crops
2025	8.57	7.57	A hailstorm caused an estimated 30% reduction in yield across all experimental plots

References

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